TARGET CALIBRATION: RETRO-REFLECTION MECHANISMS AT 2 μm

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INTRODUCTION

With the growing use of 2-μm eye-safe solid-state laser transmitters in coherent Doppler lidar applications, there is increased interest in the reflectance properties of hard target calibration materials at this wavelength. One of the factors to be considered is the polarization characteristic of the transmitter/receiver. The two fundamental lidar systems are either based upon the backscattering of linearly polarized or circularly polarized light (Kavaya, 1987). Consequently, the response of calibration materials to the particular state of polarization of the incident radiation is an important consideration. Ideally the calibration materials should have a similar reflectance response to that of the remote scattering medium that is being observed. Also the material should be most efficiently adapted to the polarization characteristics of the lidar system.

There are two measurement parameters that are useful in presenting the characteristics of polarization of reflecting materials (see References). The first is the linear polarization ratio: $\mu_l = I_{ol}/I_{sl}$, where ol denotes opposite linear and sl denotes same linear. The second is circular polarization ratio: $\mu_c = I_{sc}/I_{oc}$, where ol denotes opposite circular and sc denotes same circular. Notice that the ratios are inverted with respect to same polarization. It is the relative values of these polarization ratios that are used to characterize the retro-reflectance mechanism.

Measurement of these parameters is conveniently obtained by using the Stokes vectors corresponding to the polarized backscatter at and near the retro-angle.

diffuse scattering

RETRO-REFLECTION MECHANISMS

Two distinct processes are recognized as contributing to the retro-reflection mechanism: shadow hiding and coherent backscattering.

Shadow hiding

This type of backscattering is thought to be caused by single scattering from a particle or surface into the backward direction and tends to preserve the plane of linear polarization. However, it would reverse the handedness of circularly polarized light. Generally the forward scattered light preserves the plane of linear polarization and retains the handedness of circularly polarized light. It is clear that both μ_l and μ_c should tend to increase with scattering angles less than 180°.

Coherent backscattering

This type of backscattering is thought to be caused by multiple scattering of light. The result of multiple scattering of linearly polarized light will tend not to change the plane of polarization; thus the scattering angle dependence will appear similar for either process. However, the handedness of circularly polarized light will reverse on each impact; thus μ_c will decrease for smaller scattering angle. To distinguish between which of these mechanisms is most effective when light is incident on a particular backscattering material; the magnitudes of μ_c at the retro-angle and a few degrees off-retro need to be measured for various materials with differing surface and bulk properties.

There is another property of the retro-peak that characterizes these two mechanisms in the backscatter process, this being the angular width of the retro-peak. The shadow hiding mechanism is generally characterized by a broad peak, whereas the coherent backscattering mechanism gives rise to a very narrow peak (Gu *et al.*, 1993).

EXPERIMENT

The 2.06-μm solid state laser radiation is incident on a quarter-wave plate oriented with its optical axis at 45° with respect to the horizontal plane of polarization. This right circularly polarized beam is incident onto a 50% beamsplitter at 45° to the beam. The reflected radiation from the beamsplitter is incident onto the reflecting material set at 45° to the beam. The retro-reflected radiation is incident onto a polarimeter composed of a rotatable quarter wave plate and a linear polarizer placed before a PbS detector. The detector signal was phase detected with reference to the chopped beam. The final data were the four components of the Stokes vector for the reflected radiation.

RESULTS

Data from a selected set of calibration materials currently undergoing characterization are presented in Table 1.

MATERIAL	μ_l (retro)	μ_l (off-retro)	μ_c (retro)	μ_c (off-retro)	MECHANISM
Sulfur/acetone	0.45	0.92	1.34*	1.01	shadow/coherent
Styrofoam, HD	0.47	0.85	0.935	0.952	shadow/?
Flame-sprayed Al	0.23	0.24	0.738	0.428	?/coherent

*(Not completely reversed)

Table 1. Polarization ratios for selected target materials.

These results show that for the sulfur target both mechanisms appear to be active. By contrast, the Styrofoam measurements indicate no contribution from the coherent mechanism, whereas the converse situation applies for the case of flame-sprayed aluminum. These findings suggest that there are other physical properties, such as the scattering mean free path (Peters, 1992), which need to be defined in order to clarify the importance of the backscatter mechanism.

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